Designation: E2840 – 11 (Reapproved 2015)

Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots[1]

This standard is issued under the fixed designation E2840; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is used to assess the condition of roads and parking lots surfaced with interlocking concrete pavement through visual surveys using the Pavement Condition Index (PCI) method of quantifying pavement condition.

1.2 The PCI for roads and parking lots was developed by the U.S. Army Corps of Engineers (**1, 2**).[2] It is further verified and adopted by DOD and APWA. This standard is an adaptation of the PCI method for interlocking concrete pavements.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *additional sample, n*—a sample unit inspected in addition to the random sample units to include non representative sample units in the determination of pavement condition index. This includes very poor or excellent samples that are not typical of the section and sample units. If a sample unit containing an unusual distress is chosen at random, it should be counted as an additional sample and another random sample unit should be chosen. If all sample units are inspected, then there are no additional samples.

2.1.2 *interlocking concrete pavement, n*—discrete, hand-sized paving units with rectangular or dentated shapes manufactured from concrete and conforming to ASTM C 936. Either type of unit shape is placed in an interlocking pattern with various jointing and bedding materials over an unbound or bound base layer.

2.1.3 *pavement branch, n*—a branch is an identifiable part of the pavement network that is a single entity and has a distinct function. For example, each roadway or parking area is a separate branch of a pavement network.

2.1.4 *pavement condition index (PCI), n*—a numerical rating of the pavement condition that ranges from 0 to 100 with 0 being the worst possible condition and 100 being the best possible condition.

2.1.5 *pavement condition rating, n*—a verbal description of pavement condition as a function of the PCI value that varies from "failed" to "excellent" as shown in Fig. 1.

2.1.6 *pavement distress, n*—external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses include depressions, damaged pavers, horizontal creep and faulting. Distress types and severity levels detailed in Appendix X1 must be used to obtain an accurate PCI value.

2.1.7 *pavement sample unit, n*—a sample unit is a subdivision of the pavement section. Each pavement section is divided into sample units for the purpose of pavement inspection. The sample units for inspection shall be 2500 ft^2 ± 1000 ft^2 (225 m^2 ± 90 m^2).

2.1.8 *pavement section, n*—a contiguous pavement area having uniform construction, maintenance, usage history, and condition. A section should have the same traffic volume and load intensity.

2.1.9 *random sample, n*—a sample unit of the pavement section selected for inspection by random sampling techniques.

3. Summary of Practice

3.1 The pavement is divided into branches that are then divided into sections. Each section is divided into sample units. The type and severity of pavement distress is assessed by visual inspection of the pavement sample units. The quantity of distress is measured as described in Appendix X1 and Appendix X2. The distress data is used to calculate the PCI for each

[1] This practice is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.42 on Pavement Management and Data Needs.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

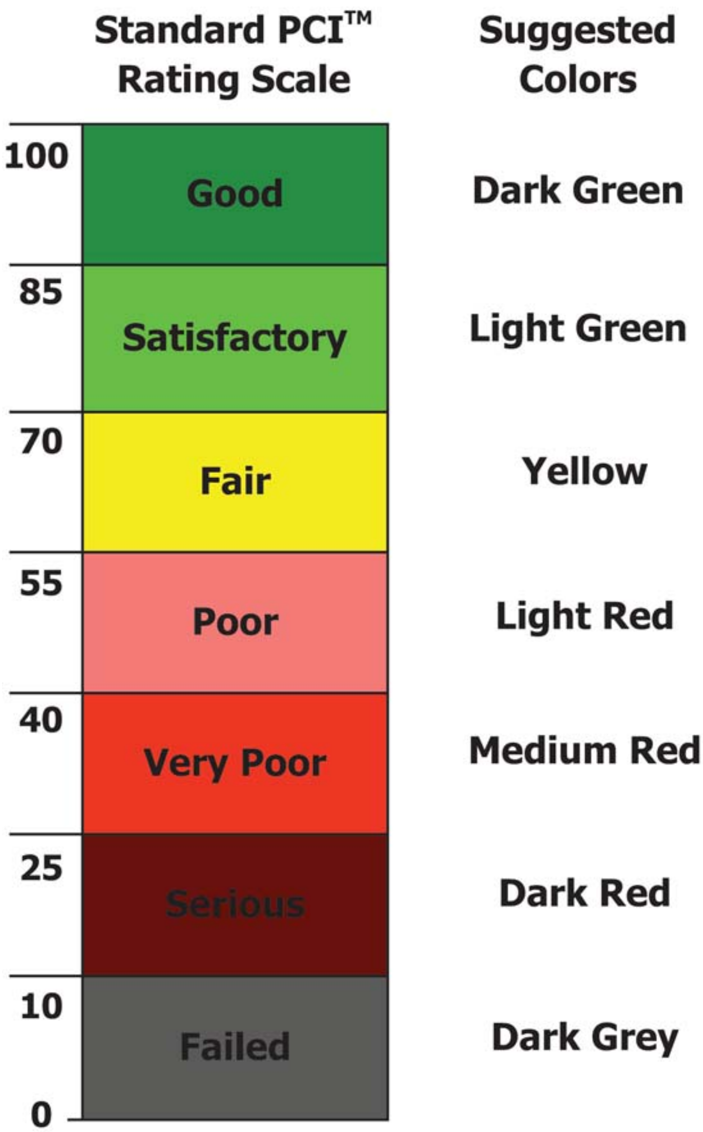

FIG. 1 Pavement Condition Index (PCI), Rating Scale, and Suggested Colors

sample unit. The PCI of a pavement section is determined based on the PCI of the inspected sample units within the section.

4. Significance and Use

4.1 The PCI is a numerical indicator that rates the surface condition of the pavement. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates the structural integrity and surface operational condition (localized roughness and safety). The PCI does not measure structural capacity nor does it provide direct measurement of skid resistance or roughness. It provides an objective and rational basis for determining maintenance and repair needs and priorities. Regular monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The PCI can also provide feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures.

4.2 The PCI procedure for interlocking concrete pavements was developed by surveying many sample units. Additional verification of the accuracy and repeatability of the PCI procedure for interlocking concrete pavements remains to be performed.

5. Apparatus

5.1 *Data Sheets*, or other field recording instruments that record the date, location, branch, section, sample unit size, distress types, severity levels, quantities, and names of surveyors. Example data sheets are shown in Fig. 2 and Fig. 3.

5.2 *Hand Odometer Wheel*, that reads to the nearest 0.1 ft (30 mm).

5.3 *Straightedge or String Line*, 10 ft (3 m).

5.4 *Scale*, 12 in. (300 mm) that reads to 1/16 in. (1 mm). An additional 12 in. (300 mm) ruler or straightedge is needed to measure faulting.

5.5 *Layout Plan*, for network to be inspected.

6. Hazards

6.1 Traffic is a hazard as inspectors may walk on the pavement to perform the condition survey.

7. Sampling and Sample Units

7.1 Identify branches of the pavement with different uses such as roadways and parking on the network layout plan.

7.2 Divide each branch into sections based on the pavement type, construction history, traffic, and condition.

7.3 Divide the pavement sections into sample units.

7.4 Individual sample units to be inspected should be marked or identified in a manner to allow inspectors and quality control personnel to easily locate them on the pavement surface. Paint marks along the edge and sketches with locations connected to physical pavement features are acceptable. It is necessary to be able to accurately relocate the sample units to allow verification of current distress data, to examine changes in condition with time of a particular sample unit, and to enable future inspections of the same sample unit if desired.

7.5 Select the sample units to be inspected. The number of sample units to be inspected may vary from the following: all of the sample units in the section, a number of sample units that provides a 95 % confidence level, or a lesser number.

7.5.1 All sample units in the section may be inspected to determine the average PCI of the section. This is usually precluded for routine management purposes by available manpower, funds, and time. Total sampling, however, is desirable for project analysis to help estimate maintenance and repair quantities.

7.5.2 The minimum number of sample units (n) that must be surveyed within a given section to obtain a statistically adequate estimate (95% confidence) of the PCI of the section is calculated using the following formula and rounding n to the next highest whole number (see Eq 1).

INTERLOCKING CONCRETE PAVEMENT
ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH ________________________ **DATE** ____________

SECTION ________________________ **SAMPLE UNIT** _______

SURVEYED BY ________________________ **SAMPLE AREA (ft^2, m^2)** _______

DISTRESS NUMBER AND TYPE

1. Damaged Pavers
2. Depressions
3. Edge Restraint
4. Excessive Joint Width
5. Faulting
6. Heave
7. Horizontal Creep
8. Joint Sand Loss/Pumping
9. Missing Pavers
10. Patching
11. Rutting

DISTRESS/ SEVERITY	QUANTITY				TOTAL	DENSITY (%)	DEDUCT VALUE

SKETCH

NOTES: ________________________________

FIG. 2 Blank Interlocking Concrete Pavement Condition Index Sheet

INTERLOCKING CONCRETE PAVEMENT
ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH Mill Street ______________________________ **DATE Sept. 8, 2010**

SECTION Main to Maple Streets ______________________ **SAMPLE UNIT All**

SURVEYED BY D. R. Smith **SAMPLE AREA [ft²] [m²] 3000 ft²**

DISTRESS NUMBER AND TYPE

1. Damaged Pavers
2. Depressions
3. Edge Restraint
4. Excessive Joint Width
5. Faulting
6. Heave
7. Horizontal Creep
8. Joint Sand Loss/Pumping
9. Missing Pavers
10. Patching
11. Rutting

DISTRESS/ SEVERITY	QUANTITY					TOTAL	DENSITY %	DEDUCT VALUE
1 L	22					22	0.73	0.40
4 M	32	33				65	2.17	12.71
3 L	42	2				44	1.47	2.94
11 L	10					10	0.33	2.96
8 L	7	2				9	0.30	0.09
2 L	1	2	3			6	0.20	2.99

SKETCH

NOTES: ______________________________

FIG. 3 Completed Interlocking Concrete Pavement Condition Index Sheet

$$n = Ns^2/((e^2/4)(N-1)+s^2) \quad (1)$$

where:

e = acceptable error in estimating the section PCI; commonly, $e = \pm 5$ PCI points;
s = standard deviation of the PCI from one sample unit to another within the section. When performing the initial inspection the standard deviation is assumed to be 10 for interlocking concrete pavements. This assumption should be checked as described below after PCI values are determined. For subsequent inspections, the standard deviation from the preceding inspection should be used to determine n; and,
N = total number of sample units in the section.

7.5.2.1 If obtaining the 95% confidence level is critical, the adequacy of the number of sample units surveyed must be confirmed. The number of sample units was estimated based on an assumed standard deviation. Calculate the actual standard deviation (s) as follows (see Eq 2):

$$s = \left(\sum_{i=1}^{n} (PCI_i - PCI_s)^2/(n-1) \right)^{\frac{1}{2}} \quad (2)$$

where:

PCI_i = PCI of surveyed sample units i,
PCI_s = PCI of section (mean PCI of surveyed sample units), and
n = total number of sample units surveyed.

7.5.2.2 Calculate the revised minimum number of sample units (Eq 1) to be surveyed using the calculated standard deviation (Eq 2). If the revised number of sample units to be surveyed is greater than the number of sample units already surveyed, select and survey more random sample units. These sample units should be spaced evenly across the section. Repeat the process of checking the revised number of sample units and surveying more random sample units until the total number of sample units surveyed equals or exceeds the minimum required sample units (n) in Eq 1, using the actual total sample standard deviation.

7.5.3 Once the number of sample units to be inspected has been determined, compute the spacing interval of the units using systematic random sampling. Samples are spaced equally throughout the section with the first sample selected at random. The spacing interval (i) of the units to be sampled is calculated by the following formula rounded to the next lowest whole number:

$$I = N/n \quad (3)$$

where:

N = total number of sample units in the section, and
n = number of sample units to be inspected.

The first sample unit to be inspected is selected at random from sample units 1 through I. The sample units within a section that are successive increments of the interval i after the first randomly selected unit also are inspected.

7.6 A reduced sampling rate than the above mentioned 95% confidence level can be used based on the condition survey objective. The following table provides an example used by some agencies for selecting the number of sample units to be inspected for other than project analysis:

Given	Survey
1 to 5 sample units	1 sample unit
6 to 10 sample units	2 sample units
11 to 15 sample units	3 sample units
16 to 40 sample units	4 sample units
over 40 sample units	10%

7.7 Additional sample units only are to be inspected when non-representative distresses are observed. The location of these sample units is determined during the survey by the inspector.

8. Inspection Procedure

8.1 The definitions and guidelines for quantifying distresses for PCI determination are given in Appendix X1. Using this test method, inspectors should identify distress types accurately 95% of the time. Linear measurements should be considered accurate when they are within 10% if remeasured, and area measurements should be considered accurate when they are within 20% if remeasured. Distress severities that one determines based on ride quality are considered subjective.

8.2 Individually inspect each sample unit chosen. Sketch the sample unit, including orientation. Record the branch and section number and the number and type of the sample unit (random or additional). Record the sample unit size measured with the hand odometer. Conduct the distress inspection by walking over the sample unit being surveyed, measuring the quantity of each severity level of every distress type present, and recording the data. Each distress must correspond in type and severity to that described in Appendix X1. The method of measurement is included with each distress description. This procedure should be repeated for each sample unit to be inspected. An example of a blank Interlocking Concrete Pavement Condition Survey Data Sheet for Sample Unit is included in Fig. 1 and a completed data sheet is shown in Fig. 2.

9. Calculation of PCI

9.1 Add up the total quantity of each distress type at each severity level, and record them in the "Total Severities" section. The units for the quantities may be either in square feet (square meters), linear feet (meters), or number of occurrences, depending on the distress type.

9.2 Divide the total quantity of each distress type at each severity level by the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.

9.3 Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves in Appendix X3.

9.4 Determine the maximum corrected deduct value (CDV). The following procedure must be used to determine the maximum CDV.

9.4.1 If none or only one individual deduct value is greater than two, the total value is used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined as follows.

9.4.2 List the individual deduct values in descending order. Determine the allowable number of deducts, m, using the following formula (see Eq 4):

$$m = 1 + (9/98)(100 - HDV) \leq 10 \quad (4)$$

where:

m = allowable number of deducts including fractions (must be ≤10),
HDV = highest individual deduct value.

9.4.3 The number of individual deduct values is reduced to the m largest deduct values, including the fractional part. If less than m deduct values are available, all of the deduct values are used.

9.4.4 Determine maximum CDV iteratively.

9.4.4.1 Determine total deduct value by summing individual deduct values. The total deduct value is obtained by adding the individual deduct values.

9.4.4.2 Determine q as the number of deducts with a value greater than 2.0.

9.4.4.3 Determine the CDV from total deduct value and q by looking up the appropriate correction curve (Appendix X3).

9.4.4.4 Reduce the smallest individual deduct value greater than 2.0 to 2.0 and repeat until q = 1. The maximum CDV is the largest of the CDVs.

9.5 Calculate PCI by subtracting the maximum CDV from 100: PCI = 100 - max CDV.

10. Determination of Section PCI

10.1 If every sample unit is surveyed then the PCI of the section is the average of the PCIs of the sample units. If additional sample units are surveyed then a weighted average is used as follows:

$$PCI_S = (N - A)(PCI_R)/N + A(PCI_A)/N \tag{5}$$

where:

PCI_S = weighted PCI of the section,
N = total number of sample units in the section,
A = number of additional sample units,
PCI_R = mean PCI of randomly selected sample units, and
PCI_A = mean PCI of additional selected sample units.

10.2 Determine the overall condition rating of the section by using the section PCI and the condition rating scale.

11. Report

11.1 Develop a summary report for each section. A summary lists section location, size, total number of sample units, the sample units inspected, the PCIs obtained, the average PCI for the section, and the section condition rating. Additional reporting and documentation may be developed at the discretion of the user.

APPENDIXES

(Nonmandatory Information)

X1. DISTRESS TYPES AND SEVERITIES

X1.1 Damaged Pavers (1)

X1.1.1 *Description*—Damaged pavers describe the condition of the pavers. Unit damage includes paver distresses such as a crack, chip, or spall. Cracks appear as thin jagged lines generally less than 1/8 in. (3 mm wide). Chips and spalls appear at portions of the edges and/or surface. Damage would be indicative of load related damage such as inadequate support causing shear breakage, etc., or weathering.

X1.1.2 *Identification*—Damaged pavers would include paver distresses such as a crack, chip or spall. Cracked pavers with little to no opening will not affect ride quality or performance.

FIG. X1.1 Low Severity Damaged Pavers

FIG. X1.2 Medium Severity Damaged Pavers

X1.1.3 *How to Measure*—Damaged pavers are measured in square feet (meters) of surface area. Random isolated pavers that are only cracked with little or no opening are not recorded. The severity is evaluated by degree of distress.

X1.1.4 *Severity Levels:*

Severity Level	Description
Low	One or two cracks with no separation, chips or spalls in the pavers
Medium	Advanced cracking with no separation, spalling, or chips in the pavers but pavers are not disintegrated
High	Pavers are in cracked into multiple pieces or are disintegrated from cracks, chips and/or spalls

FIG. X1.3 High Severity Damaged Pavers

FIG. X1.4 Low Severity Depression

X1.2 Depressions (2)

X1.2.1 *Description*—Depressions are areas of the pavement surface that have elevations that are lower than the surrounding areas. Depressions are typically not load-related and caused by settlement of the underlying subgrade or granular base. Settlement is common over utility cuts and adjacent to road hardware. Depressions can cause roughness in the pavement, and when filled with water, can cause hydroplaning of vehicles.

X1.2.2 *Identification*—Visual examination is not always a reliable technique for detection of depressions, especially for low severity depressions. The most reliable method to identify depressions is to utilize a 10 ft (3 m) straight edge. Changes in shades of color on a pavement surface can give the impression of differential elevation where none exists. The apparent depth of differential elevation is often exaggerated by shadows in the early morning and late afternoon, as well as the chamfer on the paver edges. Standing water and stains can be used to visually identify a depression, however, the boundaries and depth should be established using the straight edge. Be careful to distinguish heaves from depressions.

X1.2.3 *How to Measure*—Depressions are measured in square feet (meters) of surface area. The maximum depth of depression defines the severity. Depressions larger than 10 ft (3 m) across should be measured with a string line.

X1.2.4 *Severity Levels:*

Severity Level	Maximum Depth of Depression
Low	3/16 in. to ½ in. (5 – 13 mm)
Medium	½ to 1 in. (13 – 25 mm)
High	> 1 in. (25 mm)

FIG. X1.5 Medium Severity Depression

FIG. X1.6 High Severity Depression

X1.3 Edge Restraint Damage (3)

X1.3.1 *Description*—Edge strips and curbing are forms of restraints that provide lateral support for paver pavements. Edge strips/curbs can comprise prefabricated angle supports, concrete curbs, etc. Damage to these edge restraint systems results in lateral movement of pavers, loss of joint and bedding sand, and paver rotation. This distress is accelerated by traffic loading.

X1.3.2 *Identification*—Loss of lateral restraint is characterized by widening of the paver joints at the outer pavement edge or at the transition of pavement types. Locally pavers at the pavement edge can exhibit both vertical and horizontal rotation as well as local edge settlement. The distress is most notable within 1 ft to 2 ft (0.3 to 0.6 m) of the pavement edge.

X1.3.3 *How to Measure*—Loss of edge restraint is measured in linear feet (linear meters) of pavement edge (measure the movement of the edge restraint).

NOTE X1.1—Fig. X1.9: Edge Restraint deduct curves are for feet measurements only.

X1.3.4 *Severity Levels:*

Severity Level	
Low	Evidence of increased joint width,1/4 to 1/2 in. (6 – 13 mm) and no evidence of paver/curb rotation
Medium	Increased joint width 3/8 to1/4 in. (10 – 13 mm), with evidence of paver/curb rotation
High	Increased joint width > 0.5 in. (> 13 mm), with considerable paver/ curb rotation and local settlement

FIG. X1.7 Low Severity Loss of Edge Restraint

FIG. X1.8 Medium Severity Loss of Edge Restraint

FIG. X1.9 High Severity Loss of Edge Restraint

FIG. X1.10 Low Severity Excessive Joint Width (Approximately ¼ in. (6 mm) wide and performing well)

X1.4 Excessive Joint Width (4)

X1.4.1 *Description*—Excessive joint width is a surface distress feature in which the joints between pavers have widened. Excessive joint width can occur from a number of factors including poor initial construction, lack of joint sand, poor edge restraint, adjacent settlement/heave, etc. As joints get wider, the paver layer becomes less stiff and can lead to overstressing the substructure layers.

X1.4.2 *Identification*—Optimal paver joint spacing is typically specified as 1/16 to 3/16 in. (1.5 to 4.5 mm). As joints get wider, the individual units may show signs of rotation.

X1.4.3 *How to Measure*—Excessive joint width is measured in square feet (square meters) of surface area. The average joint width defines the severity. As most concrete pavers are manufactured with a beveled (chamfered) edge, care must be taken to ensure the actual joint width is measured.

X1.4.4 *Severity Levels:*

Severity Level	Average Joint Width
Low	¼ to 3/8 in. (6 – 10 mm)
Medium	3/8 to ½ in. (10 – 13 mm)
High	> ½ in. (13 mm)

FIG. X1.11 Medium Severity Excessive Joint Width

FIG. X1.12 High Severity Excessive Joint Width (greater than ½ in. (13 mm))

FIG. X1.13 Low Severity Faulting

X1.5 Faulting (5)

X1.5.1 *Description*—Faulting are areas of the pavement surface where the elevation of adjacent pavers differ or have rotated. Faulting can be caused by surficial settlement of the bedding sand, poor installation, pumping of the joint or bedding sand. Local roughness can reduce the ride quality. Faulting can pose a safety hazard for pedestrians. Faulting can be corrected by resetting the pavers.

X1.5.2 *Identification*—Faulting is characterized by areas of individual pavers with differential elevations. This distress is often associated with more severe distresses such as settlement, heave, rutting, etc.

X1.5.3 *How to Measure*—Faulting is measured in square feet (square meters) of surface area. The maximum elevation difference defines the severity. Measurement of differential elevation at joints is made under a straight edge of 1 ft (0.3 m) length (such as the edge of a clip board).

X1.5.4 *Severity Levels:*

Severity Level	Elevation Difference
Low	1/8 to ¼ in. (3 – 6 mm)
Medium	¼ to 3/8 in. (6 – 10 mm)
High	> 3/8 in. (10 mm)

FIG. X1.14 Medium Severity Faulting

FIG. X1.15 High Severity Faulting

FIG. X1.16 Low Severity Heave

FIG. X1.17 Medium Severity Heave

X1.6 Heave (6)

X1.6.1 *Description*—Heaves are areas of the pavement surface that have elevations that are higher than the surrounding areas. Heaves are typically caused by differential frost heave of the underlying soils. Heaves can also occur as a result of subgrade instability and can also occur in conjunction with settlement/rutting.

X1.6.2 *Identification*—Visual examination is not always a reliable technique for detection of heaves, especially for low severity heaves. The most reliable method to identify heaves is to utilize a 10 ft (3 m) straight edge.

X1.6.3 *How to Measure*—Heaves are measured in square feet (square meter) of affected surface area. Place the end of the straight edge on an adjacent non-heaved area and extend the straightedge over the heaved area. Level the straightedge over the heaved area and measure the maximum height to the adjacent non-heaved area. The maximum height of heave defines the severity. Heaves larger than 10 ft (3 m) across should be measured with a string line.

X1.6.4 *Severity Levels:*

Severity Level	Maximum Height of Heave
Low	¼ to ½ in. (6 to 13 mm)
Medium	½ in. to 1in. (13 to 25 mm)
High	> 1 in. (25 mm)

FIG. X1.18 High Severity Heave

FIG. X1.19 Low Severity Horizontal Creep

X1.7 Horizontal Creep (7)

X1.7.1 *Description*—Horizontal creep is the longitudinal displacement of the pavement caused by traffic loading. Horizontal creep should not be confused with changes in jointing patterns created by the placement of adjacent pavers at a different time.

X1.7.2 *Identification*—Regardless of the initial paver laying pattern, the pavement surface should have a uniform pattern. Shifting of the joints or pattern signifies horizontal creep.

X1.7.3 *How to Measure*—Horizontal creep is measured in square feet (square meters) of surface area. The deviation from the original position defines the severity. Severity is measured by pulling a 50 ft (15 m) long string in the longitudinal and transverse direction and measuring the distance from the string line center to the nearest line of joints. If the pavement area is less than 50 ft (15 m) in the transverse or longitudinal direction, then pull the string line across the pavement width and measure.

X1.7.4 *Severity Levels:*

Severity Level	Horizontal Movement
Low	¼ to ½ in. (6 – 13 mm) from the string line
Medium	½ to 3/4 in. (13 – 20 mm) from the string line
High	>3/4 in. (20 mm) from the string line

FIG. X1.20 Medium Severity Horizontal Creep

FIG. X1.21 High Severity Horizontal Creep

FIG. X1.22 Low Severity Joint Sand Loss

FIG. X1.23 Medium Severity Joint Sand Loss

X1.8 Joint Sand Loss/Pumping (8)

X1.8.1 *Description*—Joint sand loss/pumping is a distress feature in which the joint sand has been removed. Joint sand loss can occur from a number of factors including; heavy rain, sweeping, pressure washing, pumping under traffic loading, etc. Joint sand is considered essential to providing interlock and stiffness of the paver course.

X1.8.2 *Identification*—Joint sand loss is identified by an absence of lack of joint sand. Joint sand may be evident on the surface of the pavers or along the curbs and gutters from pumping of sand from joints.

X1.8.3 *How to Measure*—Joint sand loss/pumping is measured in square feet (square meters) of surface area. The depth of sand loss defined the severity. Most concrete pavers have a beveled edge (chamfer). Therefore, depth of sand loss is measured from the bottom of this beveled edge. Insert a thin metal ruler with the end as the zero or beginning point into the joint until the ruler stops on the sand surface within the joint. Measure from the depth of joint sand loss on the ruler.

X1.8.4 *Severity Levels:*

Severity Level	Depth of Sand Loss
Low	< 1/2 in. (13 mm)
Medium	1/2 to 1 in. (13 to 25 mm)
High	> 1 in. (25 mm)

FIG. X1.24 High Severity Joint Sand Loss

FIG. X1.25 Low Severity Missing Pavers

X1.9 Missing Pavers (9)

X1.9.1 *Description*—Missing pavers, as the name implies, refers to sections of pavement that are missing pavers, which may have resulted from removal or disintegration/damage. Missing pavers compromise the integrity of the pavement structure and promote surface roughness similar to potholes in flexible pavements.

X1.9.2 *Identification*—Sections that are missing pavers.

X1.9.3 *How to Measure*—Missing pavers are measured in square feet (square meters) of surface area. The severity is evaluated by degree of distress.

X1.9.4 *Severity Levels:*

Severity Level	
Low	Random individual missing pavers
Medium	Missing 2 or more pavers in one area and ride quality unaffected.
High	Missing 10 or more pavers in one area and ride quality affected.

FIG. X1.26 Medium Severity Missing Pavers

FIG. X1.27 High Severity Missing Pavers

X1.10 Patching (10)

X1.10.1 *Description*—Patching refers to sections of pavement that are missing pavers and have been reinstated with a dissimilar material (for example, asphalt, concrete or aggregates). Patch quality can compromise the integrity of the pavement structure and promote surface roughness similar to potholes in flexible pavements.

X1.10.2 *Identification*—Sections of dissimilar materials such as asphalt or composite materials other than pavers.

X1.10.3 *How to Measure*—Patches are measured in square feet (square meters) of surface area. The severity is evaluated by the quality of the patch.

X1.10.4 *Severity Levels:*

Severity Level	
Low	Patch is in good condition and ride quality is unaffected
Medium	Patch is in good to fair condition and ride quality is starting to deteriorate.
High	Patch is in poor condition and ride quality is affected.

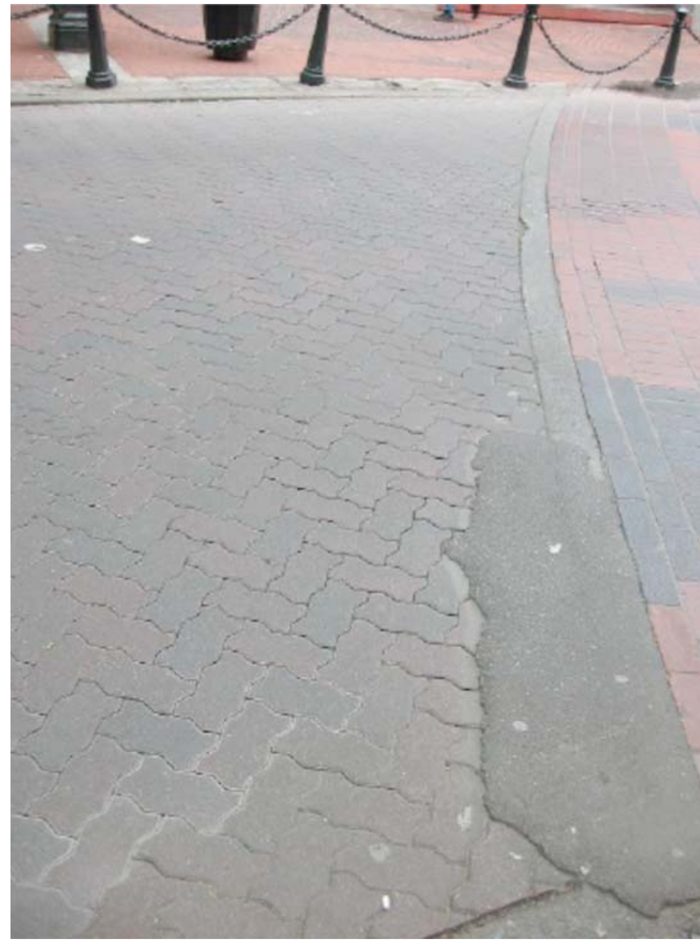

FIG. X1.28 Low Severity Patch

FIG. X1.29 Medium Severity Patch

FIG. X1.30 High Severity Patch

X1.11 Rutting (11)

X1.11.1 *Description*—Rutting is a surface depression in the wheel path and should not be confused with depressions. Depressions are areas of the pavement that have lower elevations than the surrounding areas. Rutting is typically caused by settlement of the underlying subgrade or granular base under vehicle loading. Rutting indicates a weakening or loss of bedding sand or base weakening and a loss of structural capacity. Like depressions, rutting can cause roughness in the pavement and can cause hydroplaning of vehicles when filled with water.

X1.11.2 *Identification*—Locate rutting by visual assessment and measure rutting with a straight edge. Rutting in a single wheel path is usually quite evident. However, depressions caused by static wheel loads are measured as rutting.

X1.11.3 *How to Measure*—Rutting is measured in square feet (square meters) of surface area. The maximum rut depth defines the severity. To determine the rut depth, a straight edge should be placed across the rut and the depth measured in inches (millimeters). Rut depth measurements should be taken along the length of the rut. Varying severities of rutting along the length of the rut should be measured individually.

X1.11.4 *Severity Levels:*

Severity Level	Maximum Depth of Rut
Low	1/4 to 1/2 in. (6 to 13 mm)
Medium	1/2 to 1 in. (13 to 25 mm)
High	> 1 in. (25 mm)

FIG. X1.31 Low Severity Rutting

FIG. X1.32 Medium Severity Rutting

FIG. X1.33 High Severity Rutting

X2. INTERLOCKING CONCRETE PAVEMENT SURVEY GUIDELINES

X2.1 Distress in interlocking concrete pavements and possible distress sources are in Table X2.1.

X2.1.1 Most data collection is addressed under the section "How To Measure" for each distress type and severity. Additional guidelines include the following items.

X2.1.1.1 If multiple distresses occur in the same area, each is recorded at its respective severity level.

X2.1.1.2 Distress found in a patched area is not recorded; however, its effect on the patch is considered in determining the severity level of the patch.

X2.1.1.3 Measurements of differential elevation for severity determination of area distress types are made under a 10 ft (3 m) straight edge. Measurement of differential elevation at joints is made under a straight edge of 1 ft (0.3 m) length (such as the edge of a clip board).

X2.1.1.4 1/8 in. (3 mm) is the smallest measurable elevation differential.

X2.2 Measuring linear units of distress is typically done with a calibrated measuring wheel.

X2.2.1 A measuring wheel with calibration to the nearest 1 ft (0.3 m) is recommended for layout and measurements in excess of 100 ft (30 m). For measuring distresses and for confirming sketch dimensions within a section, a measuring wheel with calibration to the nearest 1.2 in. (30 mm) is recommended.

X2.2.2 Do not attempt measurements with a wheel at a pace faster than walking. At faster speeds, the wheel tends to skip over rough pavement and can give unacceptable false readings.

X2.2.3 After measuring a length, be sure the wheel has stopped turning before lifting it from the pavement.

X2.3 Where distress occurs at sample unit boundaries, record the distress at the left and forward boundary of the sample unit. Two sample units share each boundary. This technique is intended to assure equitable documentation.

X2.4 Do not estimate the length of segments. Use the measuring wheel. It is necessary to walk each distress to measure and establish the correct quantity of each severity.

X2.5 Aluminum pipe is recommended as a straightedge. Use 1½ in. (40 mm) inside diameter Schedule 40 aluminum pipe 10 ft (3m) long. This type of straightedge is light in weight and resists bending better than iron or steel.

TABLE X2.1 Distresses in interlocking concrete pavements and possible sources

Load	Climate/Durability	Moisture/Drainage	Other Factors
Missing Pavers (9)	Joint Sand Loss/Pumping (8)	Missing Pavers (9)	Missing Pavers (9)
Damaged Pavers (1)	Missing Pavers (9)	Joint Sand Loss/Pumping (8)	Damaged Pavers (1)
Depressions (2)	Heave (6)	Depressions (2)	
Patching (10)	Patching (10)	Heave (6)	
Horizontal Creep (7)	Excessive Joint Width (4)	Patching (10)	
Edge Restraint (3)	Depressions (2)		
Rutting (11)			
Excessive Joint Width (4)			
Faulting (5) Joint Sand Loss/Pumping (8)			

X2.6 Vertical dimensions under a straightedge are best measured using a Calibrated Measuring Device (CMD). Other tools, such as a pencil, knife or the edge of a clipboard, may be used as measuring references once their key dimensions have been verified.

X2.7 Shadows under a straightedge are evidence of differential surface elevation, but they can be misleading. The appearance of differential elevation is exaggerated by shadows in early morning and late afternoon. Don't use shadows to estimate apparent elevation differences. Instead, measure them.

X2.8 Wet or discolored pavement may imply or exaggerate the appearance of differential elevation. Do not guess or estimate the apparent elevation differences. Instead, measure them.

X2.9 Depressions, ruts and heave are measured to where the straight edge meets the pavement surface. Slide a knife blade under the straight edge to establish this point, and mark with spray paint or crayon. Measure the extent of the area affected by the distress.

X2.10 On pavement with a large amount and variety of distress, an inspector can become disoriented in a sample unit. Common difficulties include measuring outside the boundaries of the sample unit, and losing track of which distresses have been measured, and which have not. If lost when sampling, the only acceptable procedure is to start over. Never guess or estimate.

X2.11 In complicated sample units, minimize the difficulty by organizing the inspection. Subdivide the sample unit with chalk or small dots of paint. If no obvious outlines are available, paint tick marks at the pavement edge and on centerline and, if necessary, at intervals along the sample unit boundaries. The essential approach is to define manageable subdivisions to assure accurate measurements.

X2.12 Keeping track of quantities of different distress severities while measuring can be difficult. If most of the distress is of one severity with only a minor amount of another severity, it may be possible to measure the total, keeping a running subtotal of the lesser severity on the bottom of the inspection sheet. In many instances, however, it will be necessary to measure each severity separately, marking transitions with spray paint or crayon.

X2.13 Where multiple severities exist within the outer boundary of a distress, identify and mark the outline of each severity, and areas with no distress. Measure and calculate each area, and record each severity.

X2.14 Pavement in poor to failed condition typically has large quantities of distress at multiple severities. In such pavement, meticulous documentation of quantities requires a great deal of time, and serves no useful purpose. It is important to make careful estimates that identify and record each and every distress type, severity, and density in the sample unit, pacing for linear dimensions and spot checking vertical relief with a straight edge. Inspection of a single sample unit should not take more than about 20 minutes.

X3. EXAMPLE PCI CALCULATION FOR MULTIPLE DISTRESSES AND SEVERITIES

X3.1 An example calculation of PCI is provided in the following section.

X3.1.1 Sample unit area = 2,500 ft^2 (232 m^2)

Distresses present = Moderate severity edge restraint (3M) = 45 ft^2 (4.2 m^2)

Low severity depression (2L) = 15 ft^2 (1.4 m^2)

Horizontal creep (7H) = 50 ft^2 (4.6 m^2)

X3.1.2 Density of distresses:

3M = 45/2500 (4.2/232) = 1.8 percent

2L = 5/2500 (1.5/232) = 0.6 percent

7H = 50/2500 (4.6/232) = 2 percent

X3.1.3 From the deduct curves, deduct value

3M = 12 (See Figure X3.3)

2L = 4 (See Figure X3.2)

7H = 10 (See Figure X3.7)

X3.1.4 The method to calculate Corrected Deduct Value (CDV) is iterative per Section 9.4. The CDV corrects the PCI to account for the superimposition of distresses. See Figure X4.1 for CDVs.

Step 1: For q = 3 and TDV = 12 + 4 + 10 = 26 , CDV = 12

Step 2: For q = 2 and TDV = 12 + 4 + 2 = 16 ,CDV = 7

Step 3: For q = 1 and TDV = 12 + 2 + 2 = 16 , CDV = 16

Select the maximum CDV from above = 16

PCI = 100 – 16 = 84

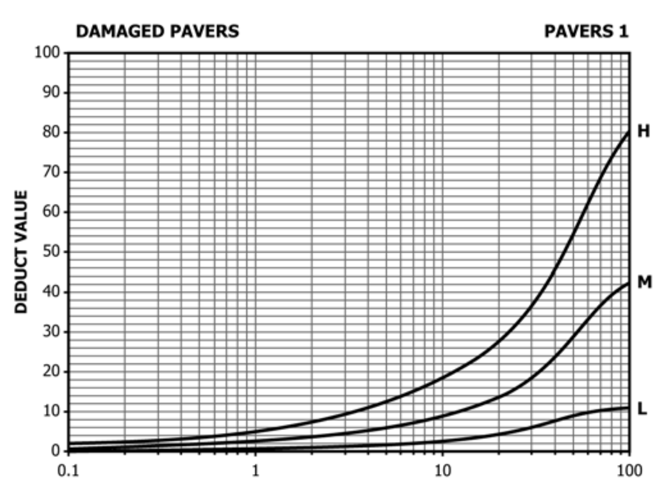

FIG. X3.1 Damaged Pavers (1)

FIG. X3.2 Depressions (2)

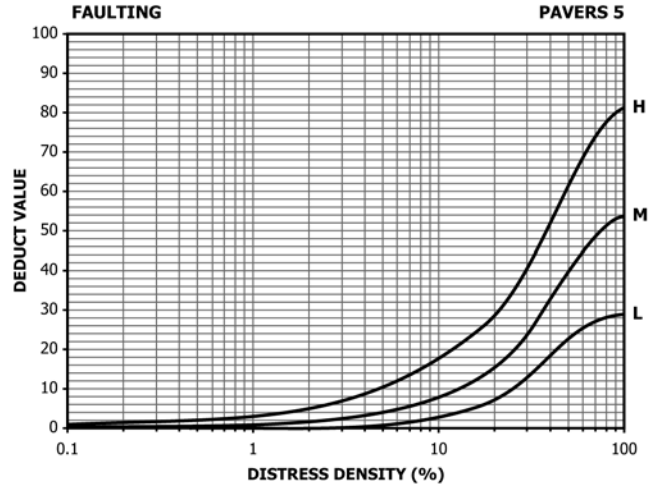

FIG. X3.5 Faulting (5)

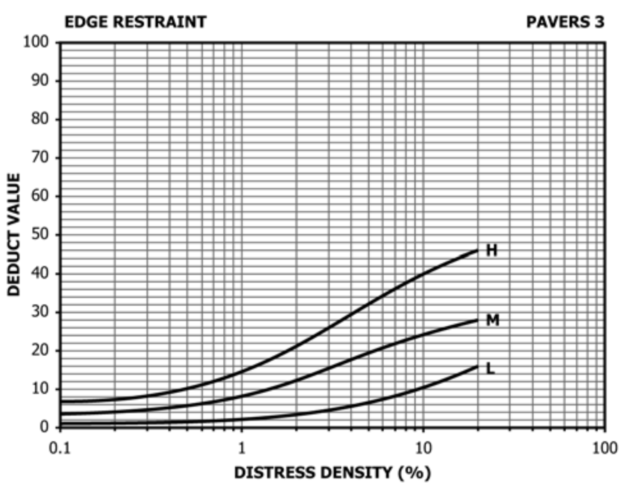

FIG. X3.3 Edge Restraint (3)

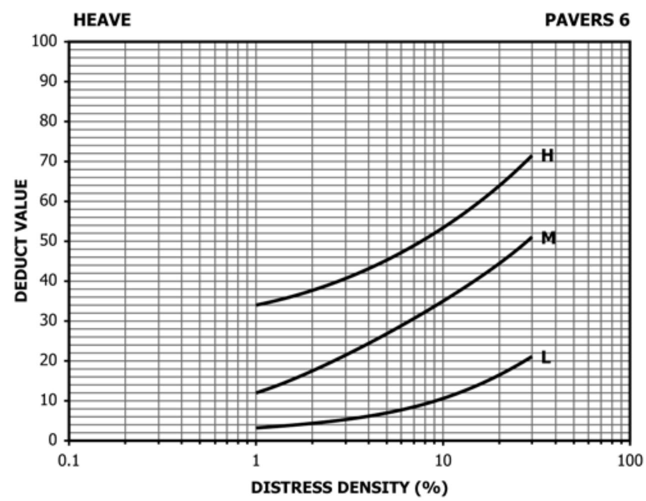

FIG. X3.6 Heave (6)

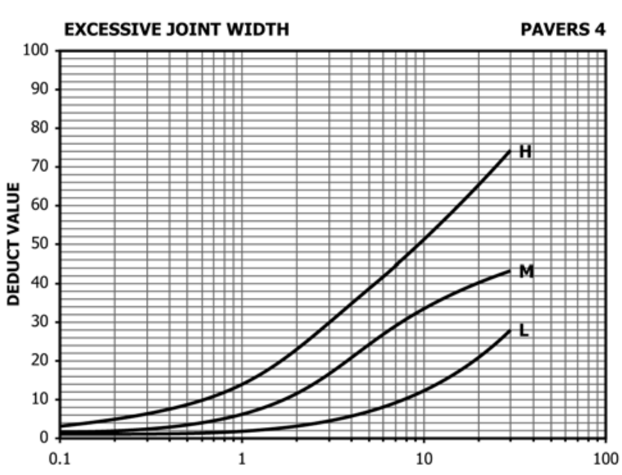

FIG. X3.4 Excessive Joint Width (4)

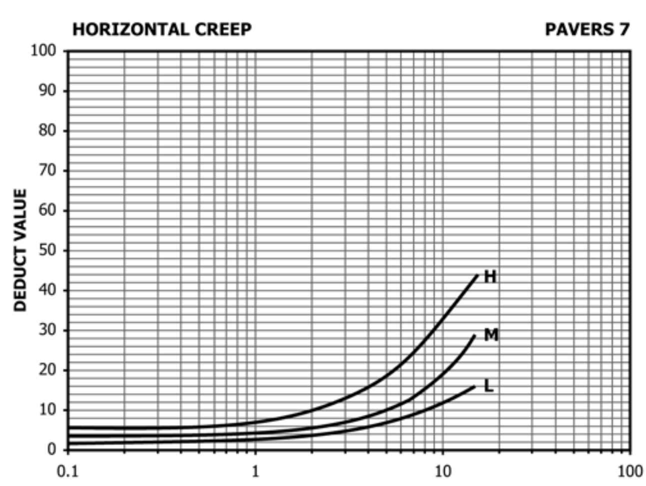

FIG. X3.7 Horizontal Creep (7)

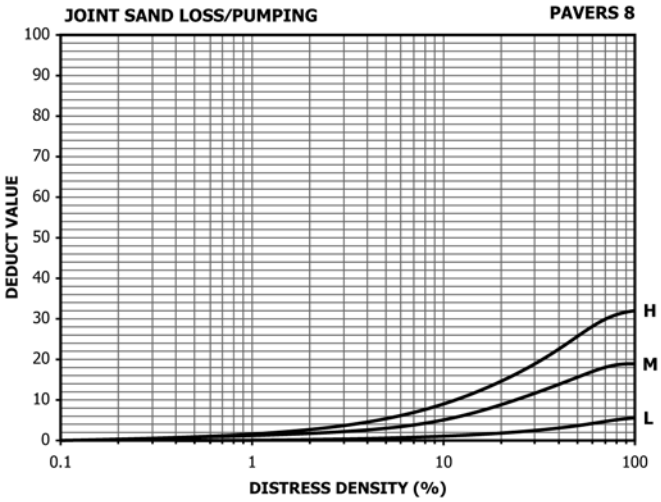

FIG. X3.8 Joint Sand Loss/Pumping

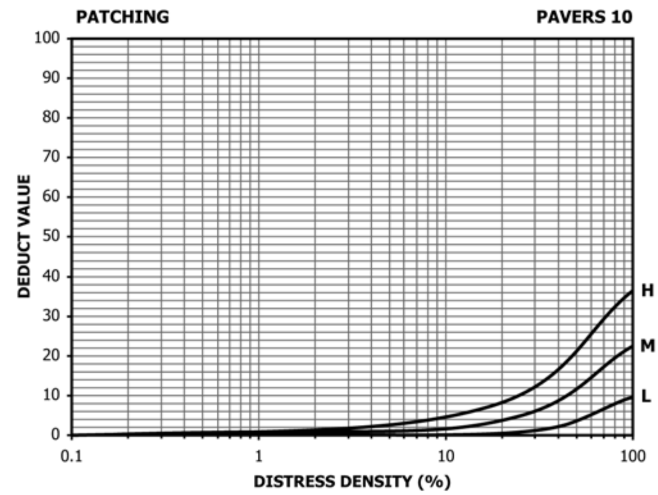

FIG. X3.10 Patching (10)

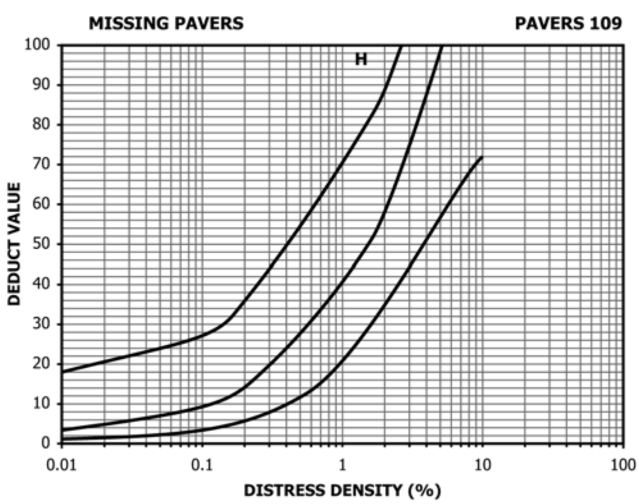

FIG. X3.9 Missing Pavers (9)

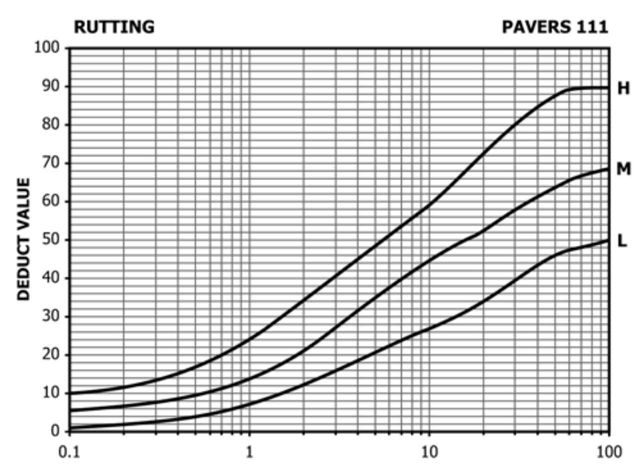

FIG. X3.11 Rutting (11)

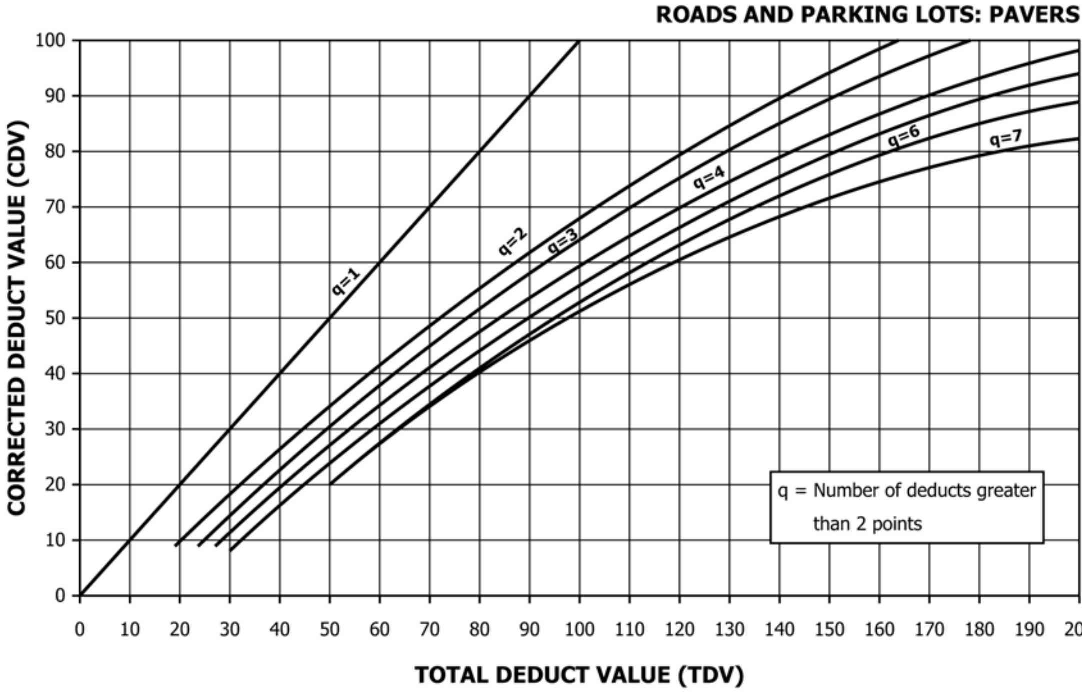

FIG. X3.12 Total Deduct Value (TDV)

REFERENCES

(1) PAVER Asphalt Distress Manual, US Army Construction Engineering Laboratories, TR97/104, June 1997.

(2) PAVER Concrete Distress Manual, US Army Construction Engineering Laboratories, TR97/105, June 1997.

(3) ASTM D 6433 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys

(4) Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways, ASCE/ICPI Standard 58-10, American Society of Civil Engineers, Reston, Virginia, 2010.